CLAIMS

I CLAIM:

1. A method of characterizing the outermost material of an article manufactured by the deposition or removal of material, to or from, a process substrate, without explicit knowledge of any previously deposited underlying layers, comprising the steps of:

a) providing a material deposition or removal chamber and an ellipsometer system configured with respect thereto so as to, in use, cause a beam of polarized electromagnetic radiation to impinge upon a process substrate therewithin during a procedure in which material deposition or removal upon said process substrate is caused to occur over a period of time;

a') obtaining ellipsometric data during material deposition or removal upon said process substrate at three distinct times (t1), (t2), and (t3);

b) using a system of analytic equations which are derived from the exact Fresnel equations that describe the interaction of electromagnetic radiation with a layered material system, such analytic equations not requiring any knowledge of the underlying layer structure previously deposited on the sample, calculating ellipsometric data at time (t3), using the ellipsometric data acquired at times (t1) and (t2), and a parameterized optical model for the outermost material deposition or removal that occurs between (t1) and (t3), and (t2) and (t3);

c) determining the optical model parameters which characterize

the outermost layer(s) by minimizing the difference between the ellipsometric data calculated at time (t3) by the analytical equations in b) and the ellipsometric data measured at time (t3), using a minimization algorithm.

2. A method of characterizing the outermost material of an article manufactured by the deposition or removal of material, to or from, a process substrate, without explicit knowledge of any previously deposited underlying layers, comprising the steps of:

a) providing a material deposition or removal chamber and an ellipsometer system configured with respect thereto so as to, in use, cause a beam of polarized electromagnetic radiation to impinge upon a process substrate therewithin during a procedure in which material deposition or removal upon said process substrate is caused to occur over a period of time;

a') obtaining ellipsometric data during material deposition or removal upon said process substrate at four distinct times (t1), (t2), (t3), and (t4);

b) using a system of analytic equations which are derived from the exact Fresnel equations that describe the interaction of electromagnetic radiation with a layered material system, such analytic equations not requiring any knowledge of the underlying layer structure previously deposited on the sample, calculating ellipsometric data:

at time (t1), using the ellipsometric data acquired at times (t2) and (t4), and a parameterized optical model for the outermost material deposition or removal that occurs between (t1) and (t2), and (t1) and (t4);

at time (t2), using the ellipsometric data acquired at times (t1) and (t3), and a parameterized optical model for the outermost material deposition or removal that occurs between (t2) and (t1), and (t2) and (t3);

at time (t3), using the ellipsometric data acquired at times (t2) and (t4), and a parameterized optical model for the outermost material deposition or removal that occurs between (t3) and (t2), and (t3) and (t4);

at time (t4), using the ellipsometric data acquired at times (t1) and (t3), and a parameterized optical model for the outermost material deposition or removal that occurs between (t4) and (t1), and (t4) and (t3);

c) determining the optical model parameters which characterize the outermost layer(s) by minimizing the differences between the ellipsometric data calculated at times (t1), (t2), (t3), and (t4) by the analytical equations in b) and the ellipsometric data measured at times (t1), (t2), (t3), and (t4) using a minimization algorithm.

3. A method of characterizing the outermost material of an article manufactured by the deposition or removal of material, to or from, a process substrate, without explicit knowledge of any previously deposited underlying layers, comprising the steps of:

a) providing a material deposition or removal chamber and an ellipsometer system configured with respect thereto so as to, in use, cause a beam of polarized electromagnetic radiation to impinge upon a process substrate therewithin during a procedure in which material deposition or removal upon said process substrate is caused to occur over a period of time;

a') obtaining ellipsometric data during material deposition or removal upon said process substrate at at least three distinct times {t1, t2, t3 ... tn};

b) using a system of analytic equations which are derived from the exact Fresnel equations that describe the interaction of electromagnetic radiation with a layered material system, such analytic equations not requiring any knowledge of the underlying layer structure previously deposited on the sample, calculating ellipsometric data:

at one time selected from the set of ellipsometric data points chosen in a'), using the ellipsometric data acquired at two other times from the set of ellipsometric data points chosen in a'), and a parameterized optical model for the outermost material deposition or removal that occurs between the selected times;

optionally at additional times selected from the set of ellipsometric data points chosen in a'), using the ellipsometric data acquired at two other times from the set of ellipsometric data points chosen in a'), and a parameterized optical model for the outermost material deposition or removal that occurs between the selected times;

c) determining the optical model parameters which characterize the outermost layer(s) by minimizing the differences between the ellipsometric data calculated at the selected times by the analytical equations in b) and the ellipsometric data measured at the selected times using a minimization algorithm.

4. A method of ellipsometrically characterizing surface material present on an article manufactured by the deposition or removal of material, to or from, a process substrate, said method requiring no explicit knowledge of prior process substrate

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said method comprising the steps of;

a) providing a material deposition and/or removal chamber, and an ellipsometer system configured with respect thereto so as to, in use, cause a beam of electromagnetic radiation to impinge upon an article therewithin during a procedure in which material deposition to, or removal from, a process substrate is caused to occur over a period of time:

a') at at least two times causing said ellipsometer system to cause a beam of electromagnetic radiation to impinge upon the article such that sufficient ellipsometric data to evaluate variable parameters which characterize the optical response of the article;

a'') in conjunction with the foregoing steps, providing a system of variable parameter containing analytic equations which describe interaction of electromagnetic radiation with a layered material system;

b) utilizing said sufficient ellipsometric data obtained in step a' and said system of variable parameter containing analytic equations provided in a'', to predict ellipsometric characterization of said article at a prediction time which is different from either of said at least two times of step a';

c) during material deposition or removal, to or from, a process substrate, obtaining ellipsometic data at a time corresponding to the prediction time of step b; and

d) utilizing said ellipsometric data obtained in step c in a

minimization algorithm to provide values for the variable parameters in at least one selection from the group consisting of:

said variable parameters in said variable parameter containing analytic equations which describe interaction of electromagnetic radiation with a layered material system provided in step a''; and

said variable parameters identified in step a' which characterized the optical response of the article;

at said prediction time in step b;

and interpreting the resulting values for said variable parameters to characterize surface material of said article at the time data was obtained in step c.

5. A method as in claim 1 in which the minimization algorithm is implemented by non-linear regression.

6. A method as in claim 2 in which the minimization algorithm is implemented by non-linear regression.

7. A method as in claim 3 in which the minimization algorithm is implemented by non-linear regression.

8. A method as in claim 4 in which the minimization algorithm is implemented by non-linear regression.

9. A method as in claim 1 in which the minimization algorithm is the Levenberg-Marquardt method.

10. A method as in claim 2 in which the minimization algorithm is the Levenberg-Marquardt method.

11. A method as in claim 3 in which the minimization algorithm is the Levenberg-Marquardt method.

12. A method as in claim 4 in which the minimization algorithm is the Levenberg-Marquardt method.

13. A method as in claim 1 in which the optical model for the outermost material deposition or removal is parameterized by at least one of the parameters from the selected list:

the material deposition rate,
the material removal rate,
the optical constants of the outermost material,
the surface roughness of the outermost material.

14. A method as in claim 2 in which the optical model for the outermost material deposition or removal is parameterized by at least one of the parameters from the selected list:

the material deposition rate,
the material removal rate,
the optical constants of the outermost material,
the surface roughness of the outermost material.

15. A method as in claim 3 in which the optical model for the outermost material deposition or removal is parameterized by at least one of the parameters from the selected list:

the material deposition rate,
the material removal rate,
the optical constants of the outermost material,
the surface roughness of the outermost material.

16. A method as in claim 4 in which the optical model for the outermost material deposition or removal is parameterized by at least one of the parameters from the selected list:

the material deposition rate,
the material removal rate,
the optical constants of the outermost material,
the surface roughness of the outermost material.

17. A method as in claim 1 in which the substrate is of a shape selected from the group consisting of:

comprising a planar surface;
of an arbitrary shape.

18. A method as in claim 2 in which the substrate is of a shape selected from the group consisting of:

comprising a planar surface;
of an arbitrary shape.

19. A method as in claim 3 in which the substrate is of a shape selected from the group consisting of:

comprising a planar surface;
of an arbitrary shape.

20. A method as in claim 4 in which the substrate is of a shape selected from the group consisting of:

comprising a planar surface;
of an arbitrary shape.

21. A method as in claim 1 in which the obtained ellipsometric data is characterized by at least one selection from the group consisting of:

it is acquired at a single wavelength;
it is acquired at a more than one wavelength;
it is acquired at a a single angle of incidence;
it is acquired at at least two angles of incidence.

22. A method as in claim 2 in which the obtained ellipsometric data is characterized by at least one selection from the group consisting of:

it is acquired at a single wavelength;
it is acquired at a more than one wavelength;
it is acquired at a a single angle of incidence;
it is acquired at at least two angles of incidence.

23. A method as in claim 3 in which the obtained ellipsometric data is characterized by at least one selection from the group consisting of:

it is acquired at a single wavelength;
it is acquired at a more than one wavelength;

it is acquired at a a single angle of incidence;
it is acquired at at least two angles of incidence.

24. A method as in claim 4 in which the obtained ellipsometric data is characterized by at least one selection from the group consisting of:

it is acquired at a single wavelength;
it is acquired at a more than one wavelength;
it is acquired at a a single angle of incidence;
it is acquired at at least two angles of incidence.